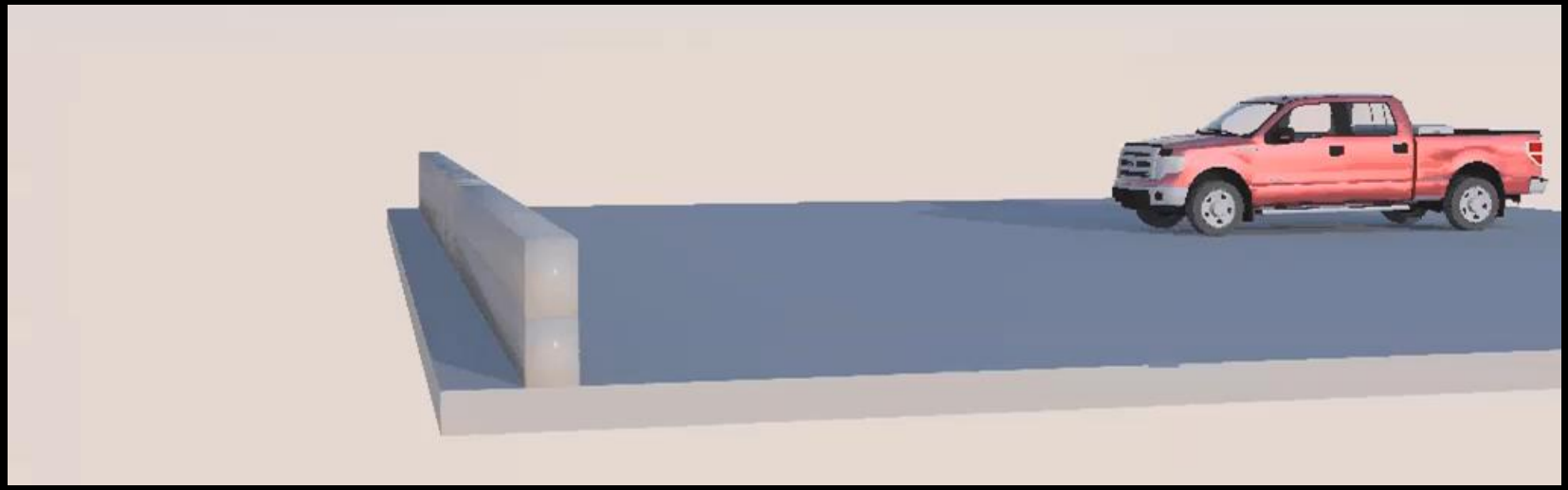
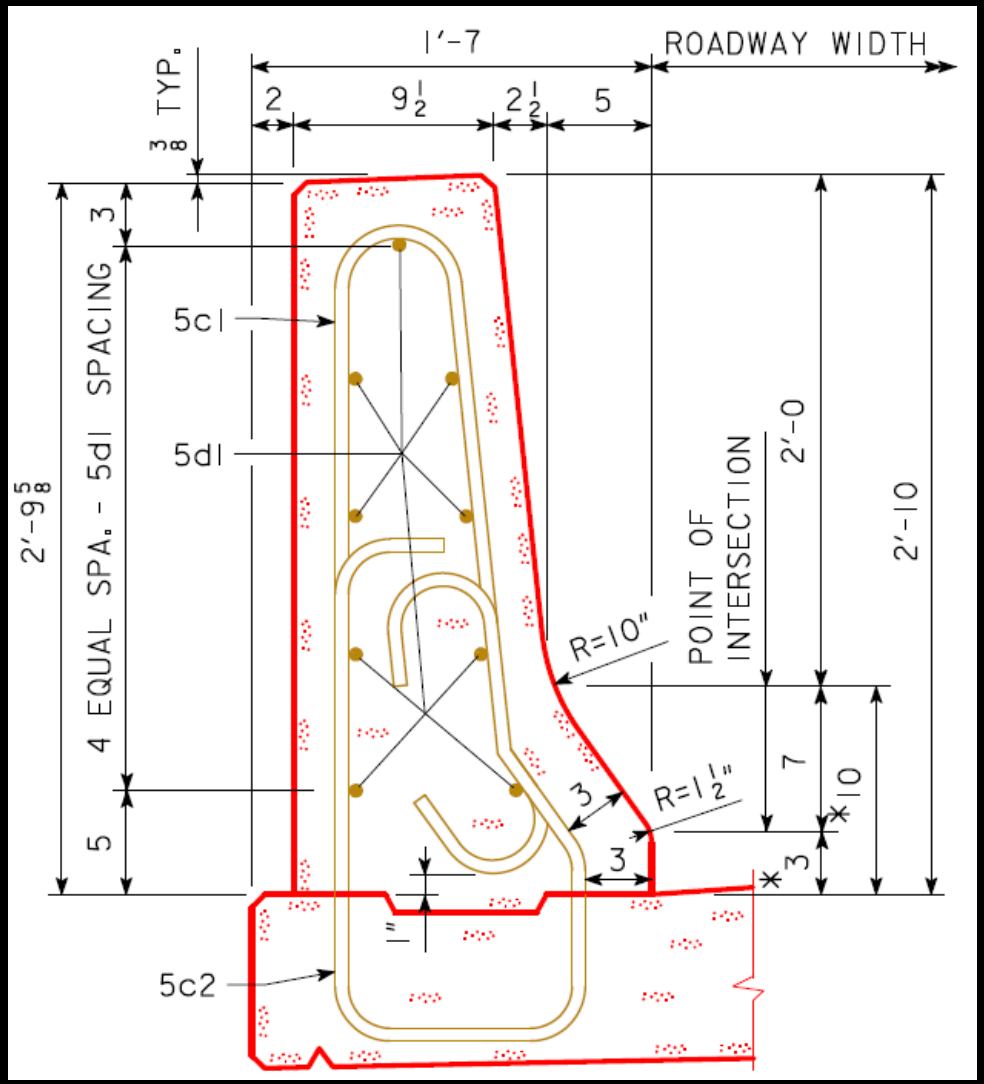
Upcoming Standard Changes

Mash

Development length / Splices



Stuart Nielsen



Barrier Rails

NCHRP 350 – “Recommended Procedures for the Safety Performance Evaluation of Highway Features”

- Publication in 1993
- Implementation in 1998 - calculations

Manual for Assessing Safety Hardware (MASH)

- Originally published in 2009 - Second edition published in 2016
- All new hardware (barrier rails) must be tested to MASH (not NCHRP 350) starting January 1, 2011

- Current bridge barrier rails designs are changing because our existing rails do not meet new the MASH requirements.
- Specifically the TL-4 rails have to have a minimum height of 36 inches instead of the current 32 inches.
- Since MASH requires a tested TL-4 rail, Road Design decided to go to a safer rail profile.

FHWA/AASHTO Bridge Implementation Plan to meet MASH

- On National Highway System (NHS)
- Bridge barriers let after December 31, 2019
- New installation or full replacement
- Existing systems do not need to be replaced
- Full testing is required; finite element analysis alone is insufficient to validate NCHRP 350 devices meets MASH

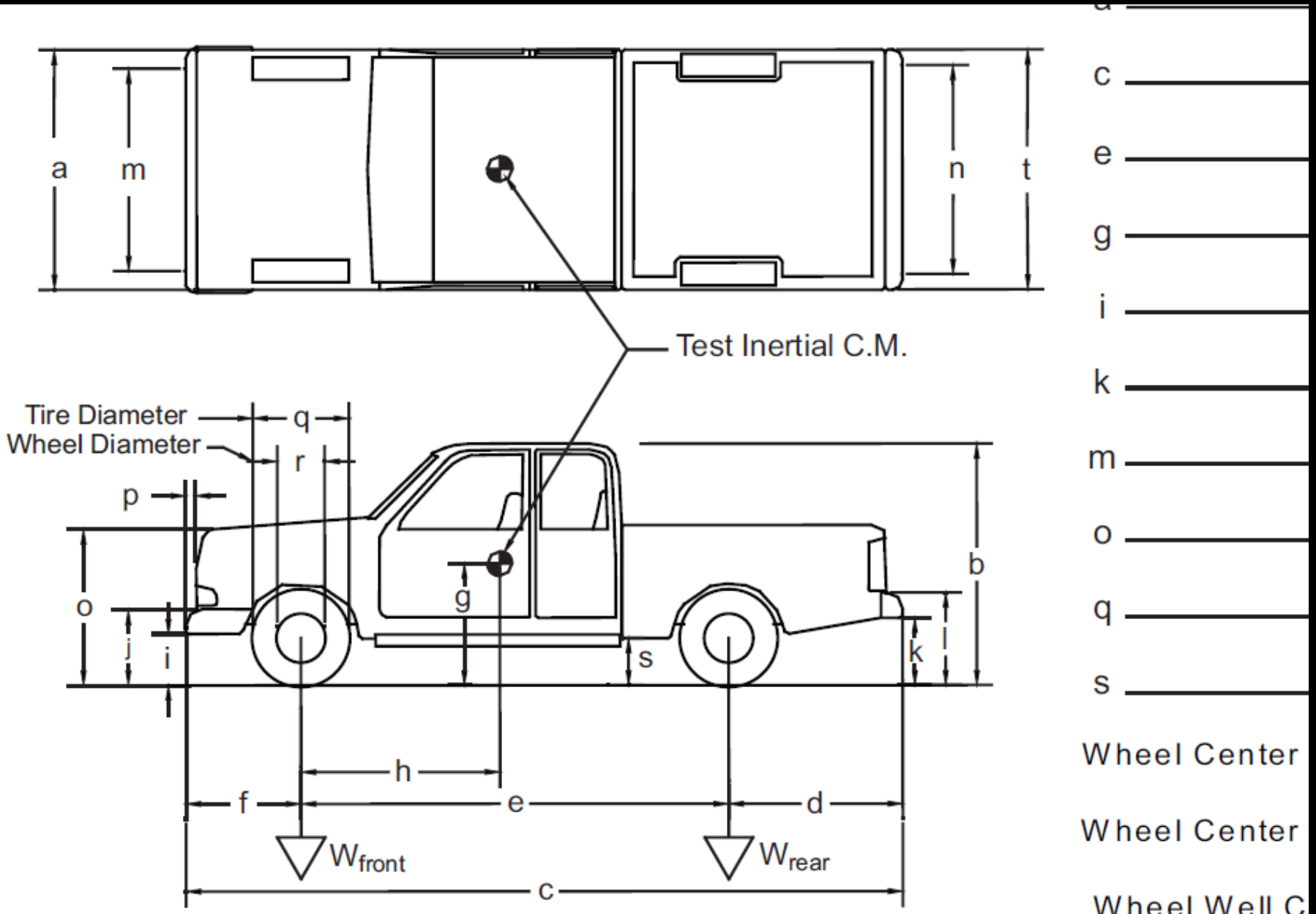
MASH

TABLE 1-1. Test Levels

Test Level	Test Vehicle Designation* and Type	Test Conditions	
		Speed mph (km/h)	Angle (degrees)
1	1100C (Passenger Car) 2270P (Pickup Truck)	31 (50) 31 (50)	25 25
2	1100C (Passenger Car) 2270P (Pickup Truck)	44 (70) 44 (70)	25 25
3	1100C (Passenger Car) 2270P (Pickup Truck)	62 (100) 62 (100)	25 25
4	1100C (Passenger Car) 2270P (Pickup Truck) 10000S (Single-Unit Truck)	62 (100) 62 (100) 56 (90)	25 25 15
5	1100C (Passenger Car) 2270P (Pickup Truck) 36000V (Tractor-Van Trailer)	62 (100) 62 (100) 50 (80)	25 25 15
6	1100C (Passenger Car) 2270P (Pickup Truck) 36000T (Tractor-Tank Trailer)	62 (100) 62 (100) 50 (80)	25 25 15

* See Chapter 2 for detailed description of each vehicle designation.

Significant differences at TL-4


a
m
n
t
Test Inertial C.M.
Tire Diameter
Wheel Diameter
q
r
p
o
j
i
g
s
k
l
b
h
f
e
d
W_{front}
W_{rear}
c
a
c
e
g
i
k
m
o
q
s
Wheel Center
Wheel Center
Wheel Well C

- Significant differences at TL-4
  - Single unit truck values have changed substantially

Value	NCHRP 350	MASH
W (kips)	18.0	22.0
G (in)	49	63
Speed (mph)	50	55

Minimum Height of TL-4 Barrier	
NCHRP 350	32”
MASH	36”

RAILINGS

13.1—SCOPE

This Section applies to railings for new bridges and for rehabilitated bridges to the extent that railing replacement is determined to be appropriate.

This Section provides six bridge railing test levels and their associated crash test requirements. Guidance for determining the level to meet the warrants for the more common types of bridge sites and guidance for structural and geometric design of railings are provided.

A process for the design of crash test specimens to determine their crashworthiness is described in Appendix A13. This methodology is based on an application of the yield line theory. For use beyond the design of test specimens with expected failure modes similar to those shown in Figures CA13.3.1-1 and CA13.3.1-2, a rigorous yield line solution or a finite element solution should be developed. The procedures of Appendix A13 are not applicable to traffic railings mounted on rigid structures, such as retaining walls or spread footings, when the cracking pattern is expected to extend to the supporting components.

C13.1

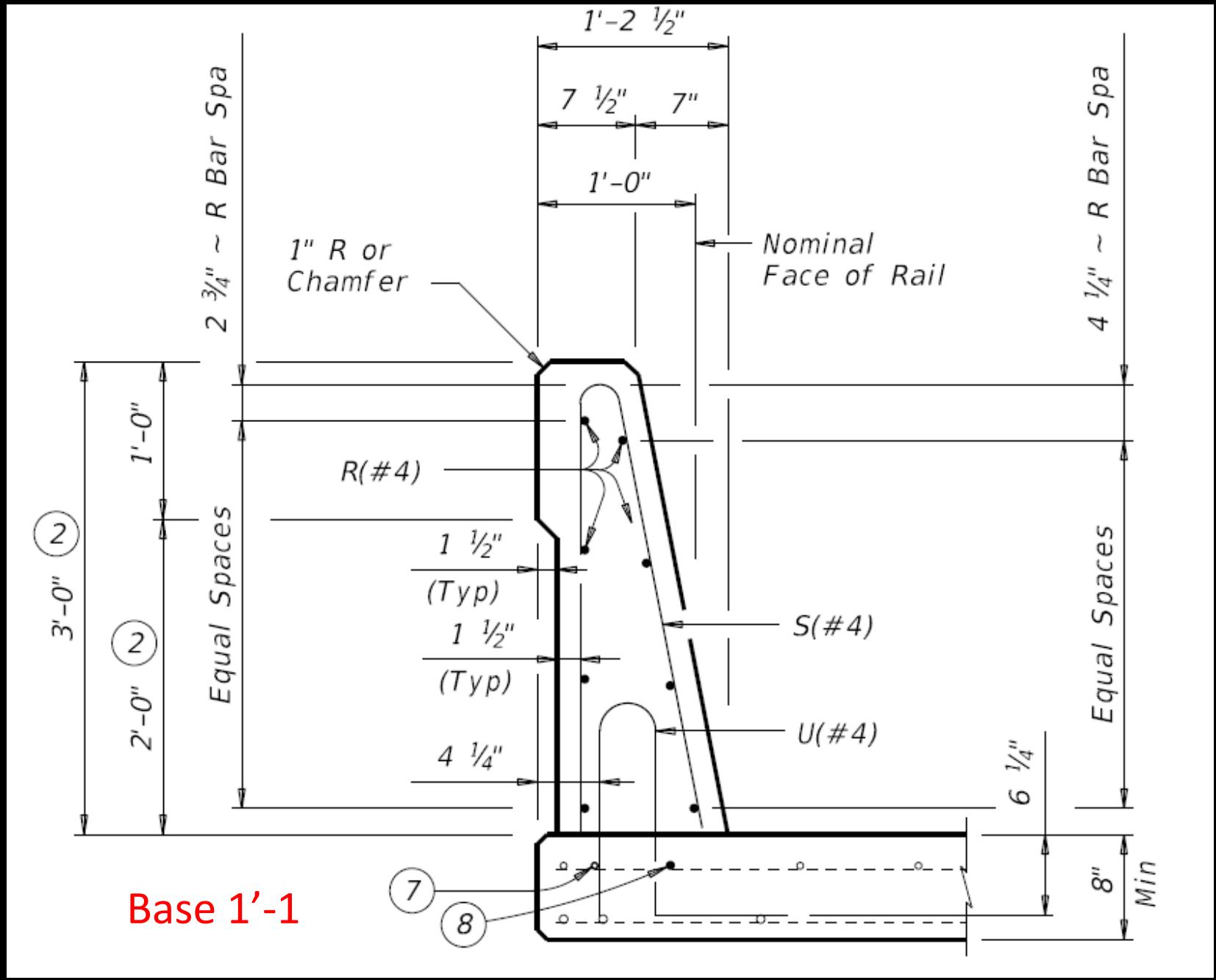
All bridge traffic barrier systems will be referred to as railings herein.

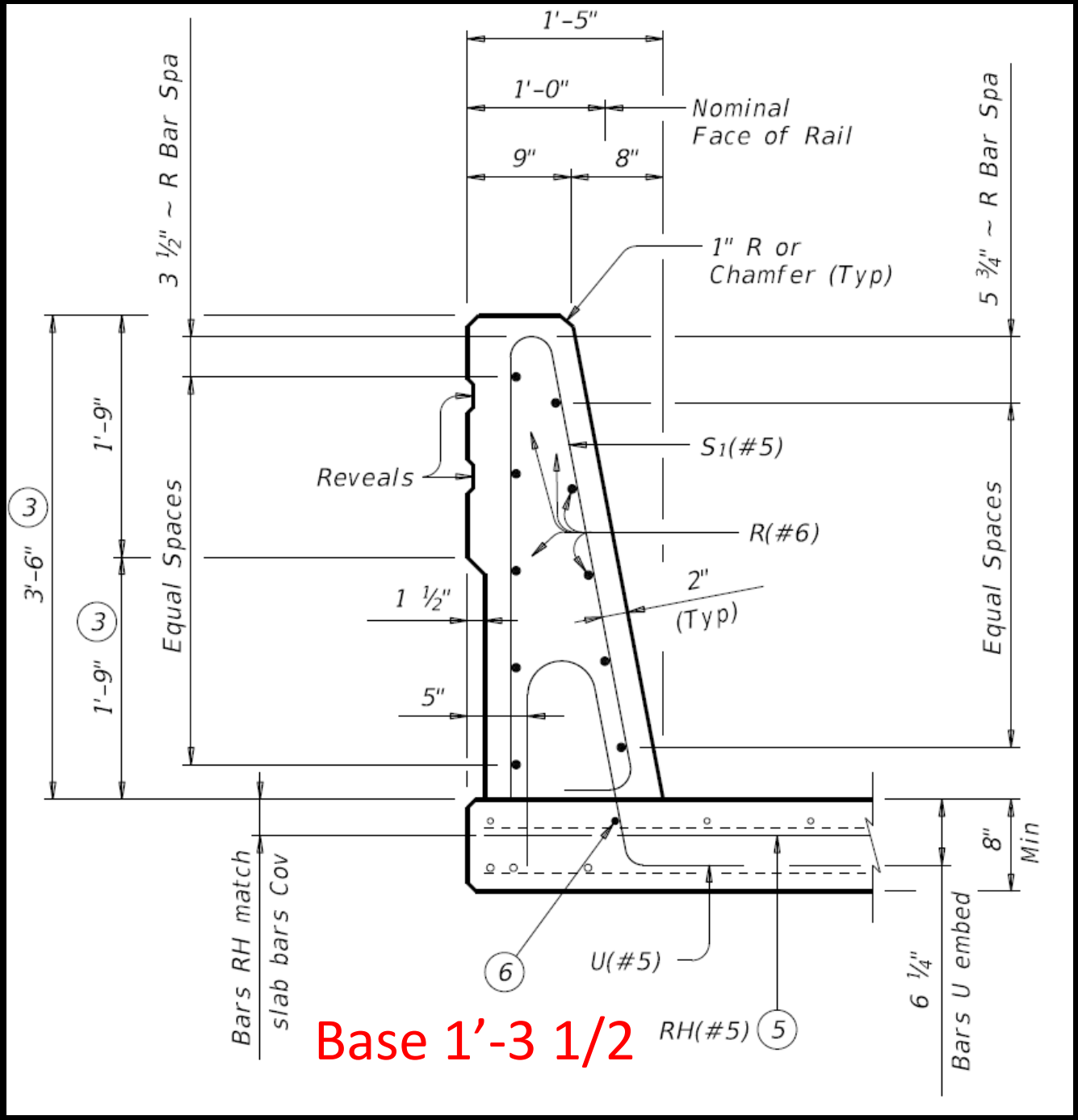
The bridge railing performance need not be identical over the whole highway network. New railing designs should match site needs leading to a multiple test level concept, as described in NCHRP Report 350 or AASHTO's *Manual for Assessing Safety Hardware*.

All highway safety hardware accepted prior to the adoption of AASHTO, *Manual for Assessing Safety Hardware* (MASH), using criteria contained in NCHRP Report 350, may remain in place and may continue to be manufactured and installed. Highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria. New highway safety hardware not previously evaluated must utilize MASH for testing and evaluation.

With the finite resources available to bridge owners, it is not reasonable to expect all existing rails to be updated any more than to expect every existing building to be immediately updated with the passing of a new building code. Many existing bridge rails have proven functional and need only be replaced when removed for bridge widenings.

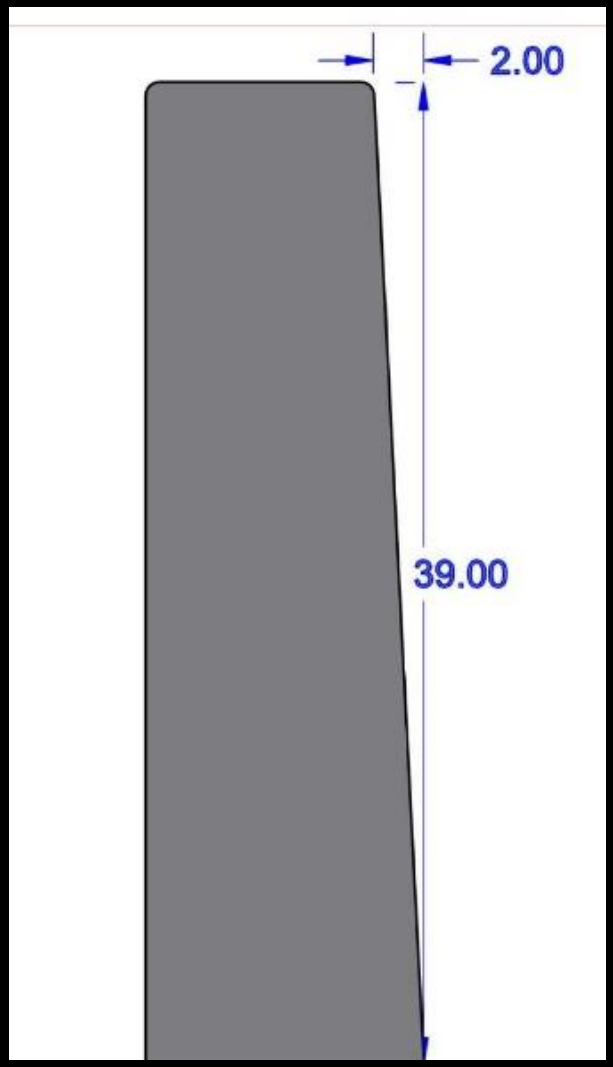
All highway safety hardware accepted prior to the adoption of AASHTO, *Manual for Assessing Safety Hardware* (MASH), using criteria contained in NCHRP Report 350, may remain in place and may continue to be manufactured and installed. Highway safety hardware accepted using NCHRP Report 350 criteria is not required to be retested using MASH criteria. New highway safety hardware not previously evaluated must utilize MASH for testing and evaluation.

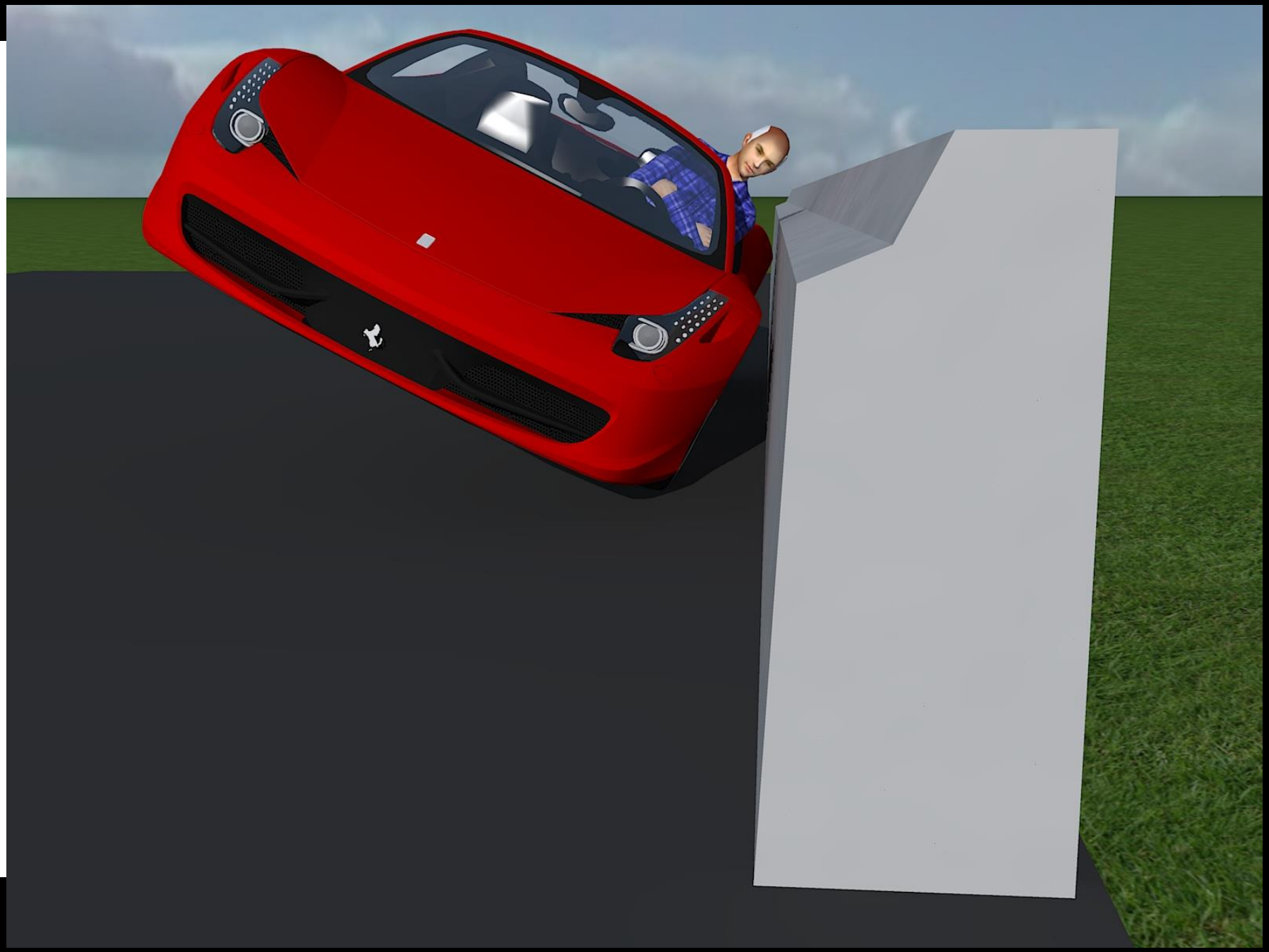

1'-2 ½"
7 ½"
7"
1'-0"
2 ¾" ~ R Bar Spa
4 ¼" ~ R Bar Spa
1" R or Chamfer
Nominal Face of Rail
R(#4)
1 ½" (Typ)
1 ½" (Typ)
S(#4)
U(#4)
4 ¼"
6 ¼"
8" Min
Equal Spaces
Equal Spaces
3'-0"
2'-0"
1'-0"
2
2
7
8
Base 1'-1


1'-5"
1'-0"
Nominal
Face of Rail
9"
8"
3 ½" ~ R Bar Spa
5 ¾" ~ R Bar Spa
1" R or
Chamfer (Typ)
S1(#5)
Reveals
R(#6)
2"
(Typ)
1 ½"
5"
Equal Spaces
Equal Spaces
3'-6"
1'-9"
1'-9"
3
3
Bars RH match
slab bars Cov
6
U(#5)
RH(#5)
5
6 ¼"
Bars U embed
8"
Min
Base 1'-3 1/2

General Barrier Shape

- Testing currently underway
- 39” Tall
  - 36” satisfy TL-4
  - 3” future overlay
- Single Slope Front Face
  - Near vertical 1:19.5
  - Vehicle stability
- Vertical Back
  - Sloped back acceptable
  - Vertical more critical






MASH TL-4
GRAVIX
DOT Precast Wall System

Development length and lap lengths

AASHTO 7th

The basic tension development length, ℓ_{db}, in inches shall be taken as:

- For No. 11 bar and smaller..... $\dfrac{1.25\,A_b f_y}{\sqrt{f'_c}}$

  but not less than ..... $0.4\,d_b f_y$

- For No. 14 bars ..... $\dfrac{2.70\,f_y}{\sqrt{f'_c}}$

- For No. 18 bars ..... $\dfrac{3.5\,f_y}{\sqrt{f'_c}}$

- For deformed wire..... $\dfrac{0.95\,d_b f_y}{\sqrt{f'_c}}$

AASHTO 8th

The modified tension development length, ℓ_d, in in. shall be taken as:

$$\ell_d = \ell_{db} \times \left(\frac{\lambda_{rl} \times \lambda_{cf} \times \lambda_{rc} \times \lambda_{er}}{\lambda} \right) \qquad (5.10.8.2.1a\text{-}1)$$

in which:

$$\ell_{db} = 2.4 d_b \frac{f_y}{\sqrt{f'_c}} \qquad (5.10.8.2.1a\text{-}2)$$

ℓ_{db} = basic development length (in.)
λ_{rl} = reinforcement location factor
λ_{cf} = coating factor
λ = concrete density modification factor as specified in Article 5.4.2.8
λ_{rc} = reinforcement confinement factor
λ_{er} = excess reinforcement factor

Splice Lengths

AASHTO 7th three classes A,B and C

Class A splice..... 1.0 ℓ_d

Class B splice..... 1.3 ℓ_d

Class C splice..... 1.7 ℓ_d

Table 5.11.5.3.1-1—Classes of Tension Lap Splices

Ratio of (A_s as provided) / (A_s as required)	Percent of A_s Spliced with Required Lap Length		
	50	75	100
≥2	A	A	B
<2	B	C	C

AASHTO 8th two classes A and B

5.10.8.4.3a—Lap Splices in Tension

The minimum length of lap for tension lap splices shall be as required for Class A or B lap splice, but not less than 12.0 in., where:

Class A splice.....1.0 ℓ_d

Class B splice..... 1.3 ℓ_d

Except as specified herein, lap splices of deformed bars and deformed wire in tension shall be Class B lap splices. Class A lap splices may be used where:

- the area of reinforcement provided is at least twice that required by analysis over the entire length of the lap splice; and
- one-half or less of the total reinforcement is spliced within the required lap splice length.

Example – tension splice

#6 epoxy coated bar 60 ksi

2” concrete cover

6” spacing

Old

Class C

ld = 22”

1.7*22”=

Lap 3’-1

New

Class B

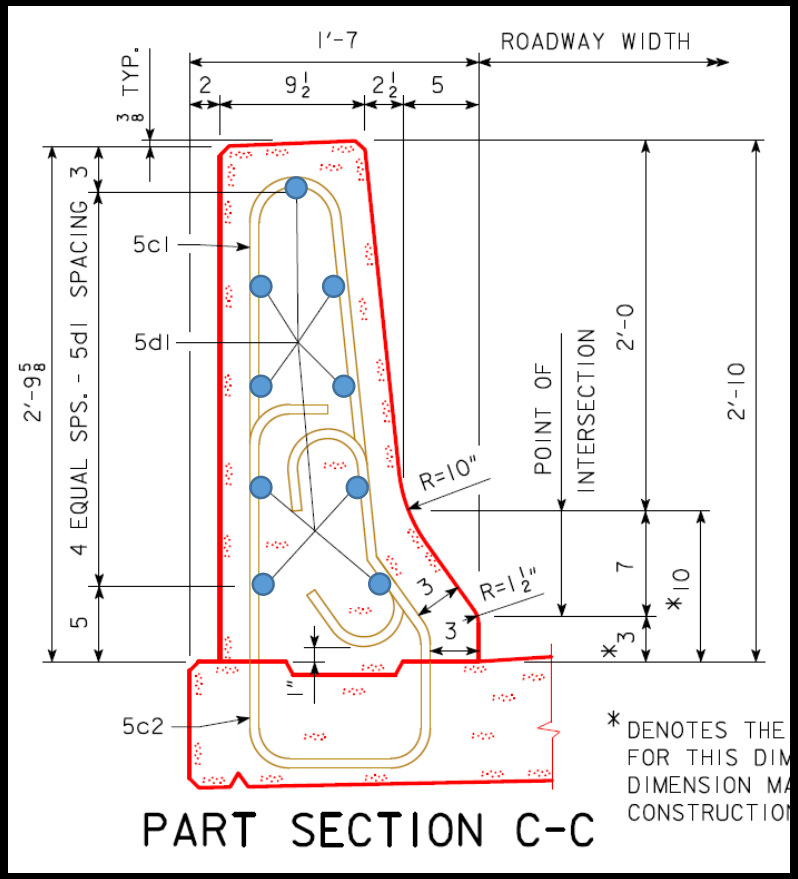
ld = 54”

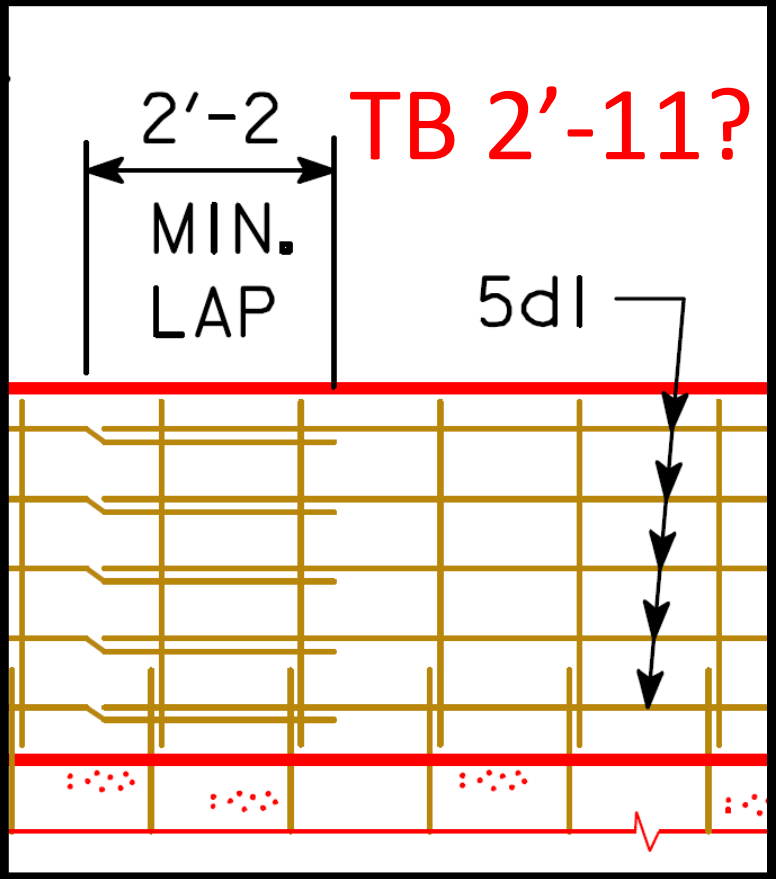
Ldf =33”

1.3*33”=

Lap 3’-7

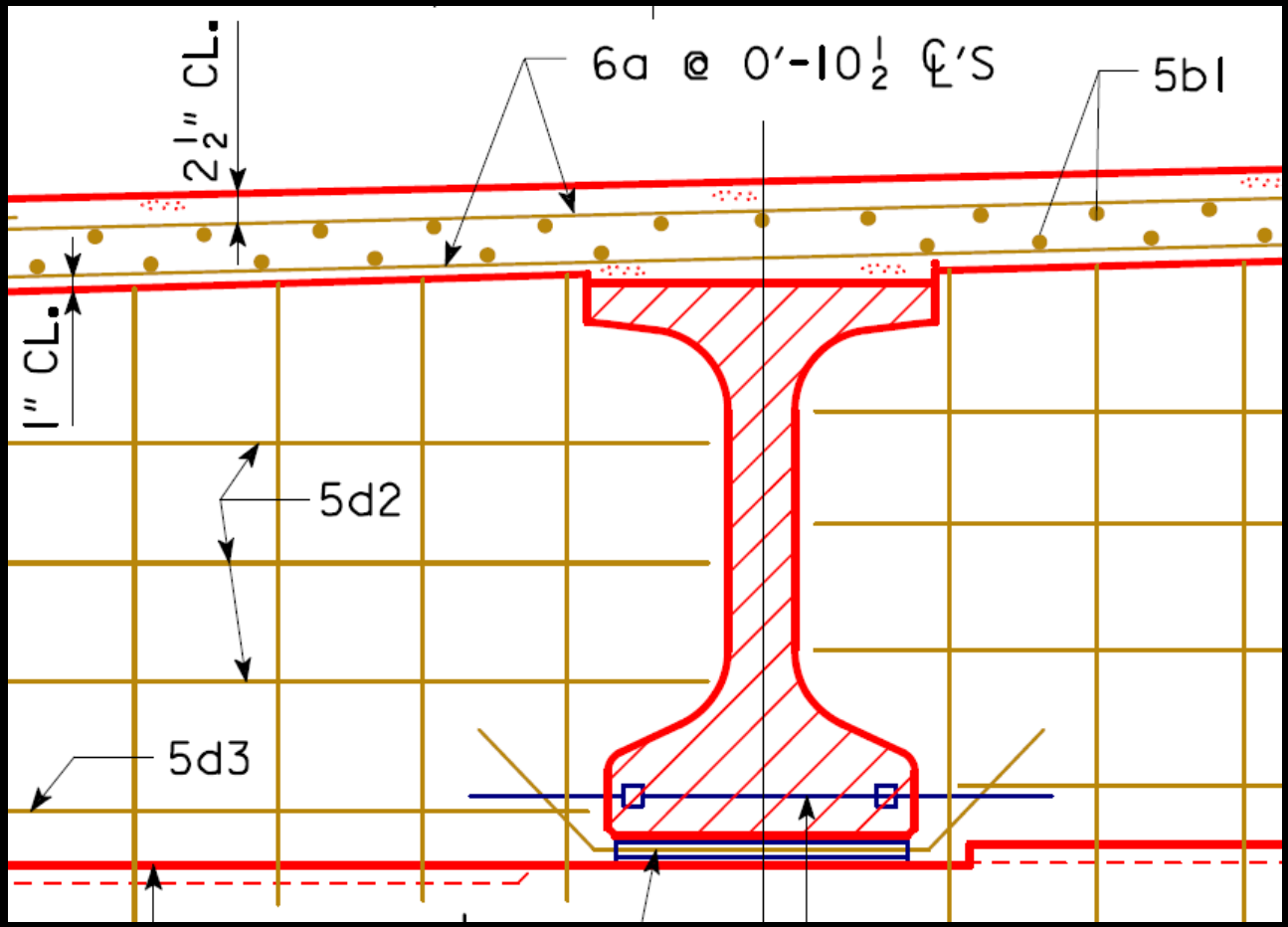
5d1 - Spacing > 6”, 2.5” cover, is it a top bar?





New 2’-5 Top Bar 3’-1

Transverse Steel Splice in a bridge deck. Length of splice? Tension?



TOP BAR - LAP MIDWAY BETWEEN BEAMS (MIN. LAP = 1'-10).
BOTTOM BARS - LAP OVER BEAMS (MIN. LAP = 1'-10).

Development Length and Tension Splice Class B (f'c = 4ksi)

		Class A	Class A	Class B	Class B	Top	Bar	Top	Bar
bar	min.	1.0*ld	1.0*ld	1.3*ld	1.3*ld	Class A	1.0*ld	Class B	1.3*ld
size	cover	s<6"	s>6"	s<6"	s>6"	s<6"	s>6"	s<6"	s>6"
#4	1"	1 '- 10 "	1 '- 10 "	2 '- 5 "	2 '- 5 "	2 '- 1 "	2 '- 1 "	2 '- 8 "	2 '- 8 "
	1.5-2"	1 '- 10 "	1 '- 6 "	2 '- 5 "	1 '- 11 "	2 '- 1 "	1 '- 11 "	2 '- 8 "	2 '- 6 "
	2.5"	1 '- 10 "	1 '- 6 "	2 '- 5 "	1 '- 11 "	2 '- 1 "	1 '- 11 "	2 '- 8 "	2 '- 6 "
#5	1"	2 '- 9 "	2 '- 9 "	3 '- 6 "	3 '- 6 "	3 '- 1 "	3 '- 1 "	4 '- 0 "	4 '- 0 "
	1.5-2"	2 '- 5 "	2 '- 3 "	3 '- 1 "	3 '- 0 "	2 '- 8 "	2 '- 7 "	3 '- 6 "	3 '- 4 "
	2.5"	2 '- 5 "	1 '- 10 "	3 '- 1 "	2 '- 5 "	2 '- 8 "	2 '- 5 "	3 '- 6 "	3 '- 1 "
#6	1"	3 '- 9 "	3 '- 9 "	4 '- 10 "	4 '- 10 "	4 '- 3 "	4 '- 3 "	5 '- 6 "	5 '- 6 "
	1.5-2"	3 '- 5 "	2 '- 9 "	4 '- 5 "	3 '- 7 "	3 '- 10 "	3 '- 1 "	5 '- 0 "	4 '- 0 "
	2.5"	3 '- 5 "	2 '- 2 "	4 '- 5 "	2 '- 10 "	3 '- 10 "	2 '- 10 "	5 '- 0 "	3 '- 8 "
#7	1"	4 '- 10 "	4 '- 10 "	6 '- 3 "	6 '- 3 "	5 '- 6 "	5 '- 6 "	7 '- 1 "	7 '- 1 "
	1.5"	4 '- 0 "	3 '- 7 "	5 '- 2 "	4 '- 8 "	4 '- 6 "	4 '- 1 "	5 '- 10 "	5 '- 3 "
	2.0"	4 '- 0 "	3 '- 2 "	5 '- 2 "	4 '- 2 "	4 '- 6 "	3 '- 7 "	5 '- 10 "	4 '- 8 "
	2.5"	4 '- 0 "	3 '- 2 "	5 '- 2 "	4 '- 2 "	4 '- 6 "	3 '- 7 "	5 '- 10 "	4 '- 8 "
#8	1"	6 '- 0 "	6 '- 0 "	7 '- 10 "	7 '- 10 "	6 '- 10 "	6 '- 10 "	8 '- 11 "	8 '- 11 "
	1.5"	5 '- 2 "	4 '- 6 "	6 '- 9 "	5 '- 11 "	5 '- 10 "	5 '- 2 "	7 '- 7 "	6 '- 8 "
	2.0"	5 '- 2 "	3 '- 8 "	6 '- 9 "	4 '- 9 "	5 '- 10 "	4 '- 1 "	7 '- 7 "	5 '- 4 "
	2.5"	5 '- 2 "	3 '- 8 "	6 '- 9 "	4 '- 9 "	5 '- 10 "	4 '- 1 "	7 '- 7 "	5 '- 4 "
#9	1"	7 '- 4 "	7 '- 4 "	9 '- 7 "	9 '- 7 "	8 '- 4 "	8 '- 4 "	10 '- 10 "	10 '- 10 "
	1.5"	6 '- 7 "	5 '- 7 "	8 '- 7 "	7 '- 3 "	7 '- 5 "	6 '- 4 "	9 '- 8 "	8 '- 3 "
	2.0"	6 '- 7 "	4 '- 6 "	8 '- 7 "	5 '- 10 "	7 '- 5 "	5'- 1 "	9 '- 8 "	6 '- 7 "
	2.5"	6 '- 7 "	4 '- 1 "	8 '- 7 "	5 '- 4 "	7 '- 5 "	4 '- 8 "	9 '- 8 "	6 '- 0 "
#10	1"	8 '- 11 "	8 '- 11 "	11 '- 7 "	11 '- 7 "	10 '- 1 "	10 '- 1 "	13 '- 1 "	13 '- 1 "
	1.5"	7 '- 4 "	6 '- 10 "	9 '- 6 "	8 '- 11 "	8 '- 3 "	7 '- 9 "	10 '- 9 "	10 '- 1 "
	2.0"	7 '- 4 "	5'- 7 "	9 '- 6 "	7 '- 2 "	8 '- 3 "	6 '- 3 "	10 '- 9 "	8 '- 2 "
	2.5"	7 '- 4 "	4 '- 11 "	9 '- 6 "	6 '- 4 "	8 '- 3 "	5 '- 6 "	10 '- 9 "	7 '- 2 "
#11	1"	10 '- 6 "	10 '- 6 "	13 '- 8 "	13 '- 8 "	11 '- 11 "	11 '- 11 "	15 '- 6 "	15 '- 6 "
	1.5"	9 '- 0 "	8 '- 2 "	11 '- 8 "	10 '- 7 "	10 '- 2 "	9 '- 3 "	13 '- 3 "	12 '- 0 "
	2.0"	9 '- 0 "	6 '- 8 "	11 '- 8 "	8 '- 8 "	10 '- 2 "	7 '- 6 "	13 '- 3 "	9 '- 9 "
	2.5"	9 '- 0 "	6 '- 0 "	11 '- 8 "	7 '- 10 "	10 '- 2 "	6 '- 10 "	13 '- 3 "	8 '- 10 "

		Class A	Class A	Class B	Class B
bar	min.	1.0*ld	1.0*ld	1.3*ld	1.3*ld
size	cover	s<6"	s>6"	s<6"	s>6"
#4	1"	1 '- 10 "	1 '- 10 "	2 '- 5 "	2 '- 5 "
	1.5-2"	1 '- 10 "	1 '- 6 "	2 '- 5 "	1 '- 11 "
	2.5"	1 '- 10 "	1 '- 6 "	2 '- 5 "	1 '- 11 "
#5	1"	2 '- 9 "	2 '- 9 "	3 '- 6 "	3 '- 6 "
	1.5-2"	2 '- 5 "	2 '- 3 "	3 '- 1 "	3 '- 0 "
	2.5"	2 '- 5 "	1 '- 10 "	3 '- 1 "	2 '- 5 "
#6	1"	3 '- 9 "	3 '- 9 "	4 '- 10 "	4 '- 10 "
	1.5-2"	3 '- 5 "	2 '- 9 "	4 '- 5 "	3 '- 7 "
	2.5"	3 '- 5 "	2 '- 2 "	4 '- 5 "	2 '- 10 "

Future

- Projects started after October 1, 2018 shall use the AASHTO 8th edition
- Standards will be updated as fast as possible for MASH and splices / development lengths
- Use standards “AS IS” until new standards are updated
- Non standard designs use new AASHTO 8th development lengths (projects started after October 1, 2018).

Questions?